LA-UR-80-3423

CONF-810408--1

TITLE: FIBER FELTS AS LOW DENSITY STRUCTURAL MATERIALS

AUTHOR(S): John V. Milewski
Stephen E. Newfield

MASTER

SUBMITTED TO: SAMPE Symposium/Exhibition
Los Angeles, CA, April 28-30, 1981

University of California

LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663 Los Alamos, New Mexico 87545
An Affirmative Action/Equal Opportunity Employer

FIBER FELTS AS LOW DENSITY STRUCTURAL MATERIALS

John V. Milewski
Stephen E. Newfield
Los Alamos Scientific Laboratory
Los Alamos, New Mexico

Abstract

Short fiber felts structures can be made which provide improvements in properties over foams. In applications where resistance to compression set or stress relaxation are important, bonded fiber felts excel due to the flexing of individual fibers within their elastic limit. Felts of stainless steel and polyester fibers were prepared by deposition from liquid slurries. Compressive properties were determined as a function of felt parent material, extent of bonding, felt density, and length-to-diameter (L/D) ratio of starting fibers.

1. INTRODUCTION

By felting short fibers of various materials and subsequently bonding the fibers together at their intersections, low density materials can be made that have interesting physical properties. The ultimate properties obtained are a function of several variables, including: fiber material; bonding medium; and length-to-diameter (L/D) ratio of fiber used.

A laboratory-scale technique was developed for felting and coating fibers. Some physical properties have been determined for sample felts as functions of L/D, fiber material and extent of felt coating. In layers up to 12.7 mm thick, such felts could be used as cushions with attractive properties. By selecting fibers such as carbon or stainless steel, the stress relaxation and compression set failure of the cushion could be greatly reduced, since individual brittle fibers could flex within their elastic limit without deformation.

2. FELT FABRICATION

Fibers in various metal, ceramic and polymeric materials are becoming increasingly available commercially. Figure 1 shows four-μm-diam stainless steel fibers chopped into one-mm in length. The fibers are frequently supplied in ribbon-like bundles, held lightly together with an organic sizing material.

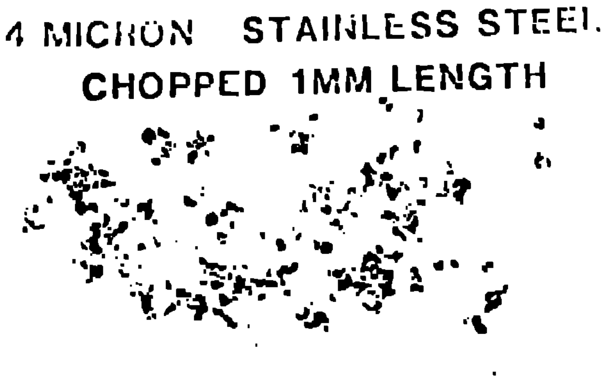


Figure 1. Fibers Bundles.

The fiber bundles were separated into individual fibers by vigorous agitation in hot water. The suspending liquid was then changed to isopropanol. Figure 2 shows the individual fibers as they were being agitated in the alcohol.

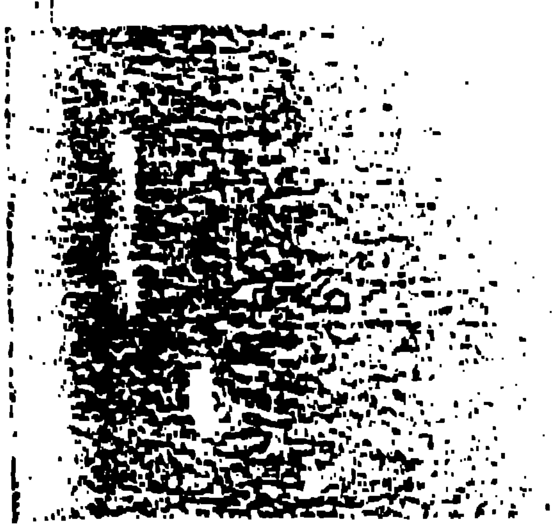


Figure 2. Fibers in alcohol.

In Figure 3, a Buchner funnel with a fritted glass filter is shown inverted into the agitated suspension. A vacuum drew the fiber-liquid suspension into the funnel, and the fibers deposited on the filter as a felt.

Figure 3. Inverted Buchner funnel with vacuum.

Figure 4 shows a deposited felt on the filter.

Figure 4. Felt on Fritted Filter.

In order to bond the fibers together, a water-soluble resin solution of hair spray was drawn thourgh the felt and it was allowed to dry. A felt prepared in this manner will be referred to as "bonded fibers," since the "coated" felts will be subjected to further coating procedures.

A coating was added by drawing an epoxy resin solution with curing agent through the felt. This leaves the felt wet with solution. The solvent evaporates and the epoxy cures. Coating extent can be controlled by solution concentration.

The types of organic coatings which can be used are quite extensive. For tensile strength, strong resins such as polycarbonate could be applied to inorganic felts by solution and subsequently heat treated to form very strong hot-melt bonds.[1] Elastomeric coatings could be used where rubbery linkage of fibers is needed.

A conductive felt could be electroplated with a metal coating. The potential for such materials composites will be the focus of future work.

Figure 5 shows various materials which have been felted by the technique described.

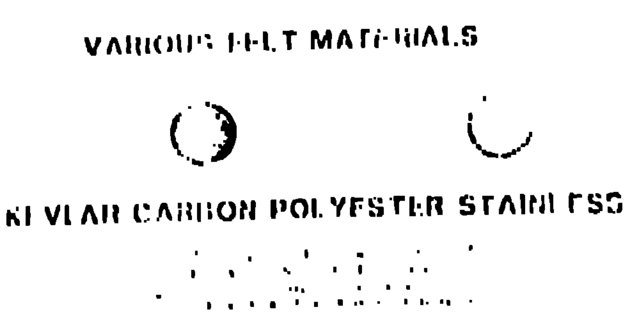


Figure 5. Various felted materials.

Figure 6 shows hemispherical shell geometries.

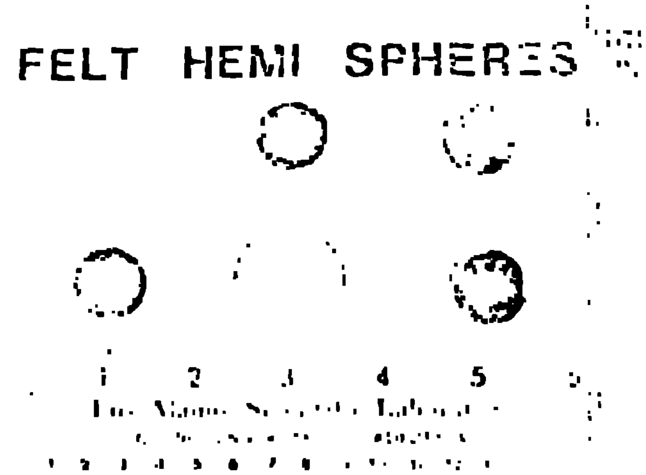


Figure 6. Hemisphrical felts.

3. PROPERTIES TESTING

The assembly shown in Figure 7 was used to measure compressive properties of several felts.

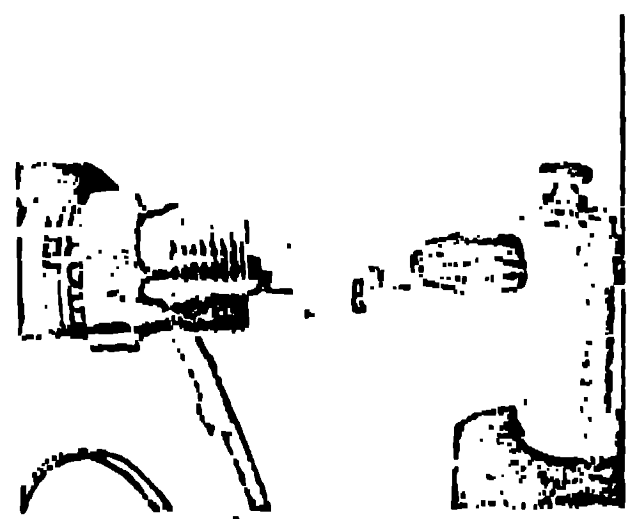


Figure 7. Compression test assembly.

The white felt in the center is compressed through a recording load cell against a fixed post. Figure 8 shows a typical chart recording of 5.0 gram increments of load. The compressive data will be presented later to help show the effects of the felt construction variables.

The reproducibility of felts was determined by measuring the volume of solids content for several samples of stainless steel and polyester fiber felts.

COMPRESSION TESTING

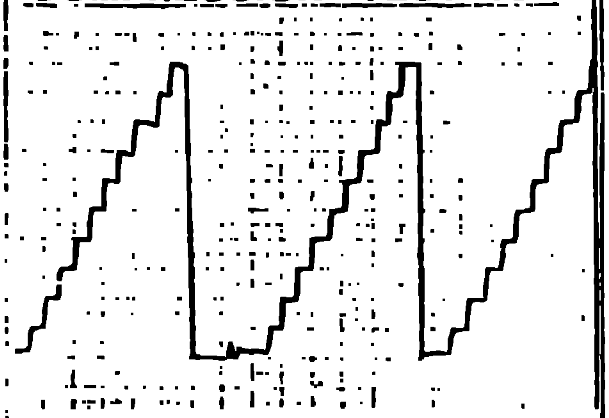
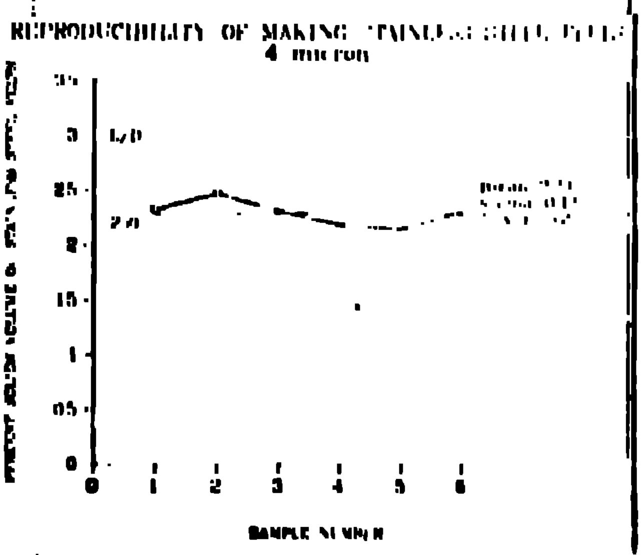


Figure 8.

Figure 9 shows the spread of data for stainless steel felts made from fibers 1000 µm long x 4 µm diam, an L/D of 250.



Figurr 9.

Figure 10 shows similar data for polyester felts from fibers of different L/D's. Percent solids volume (and therefore density) becomes lower as the L/D becomes greater.

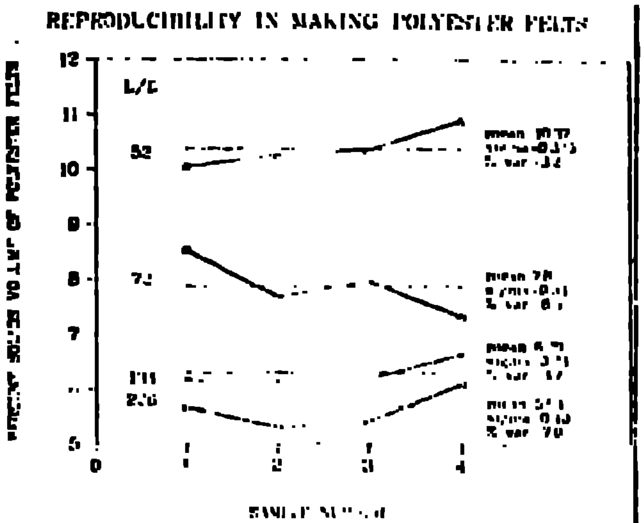


Figure 10.

Figure 11 shows the relationship of L/D to density, expressed as percent solids volume. This re-

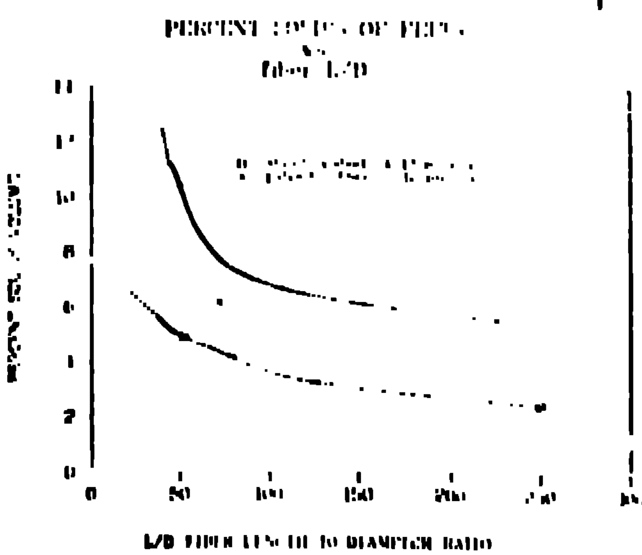


Figure 11.

sult is not unexpected, with shorter fiber showing greater density, insofar as shorter fibers can be expected to orient and pack more, with fewer bridging interactions. Figure 12 shows the expected linear relationship of coating added to coating solution concentration. The coating medium for this work was Epon (*)828, an epicholorohydrin - bis-phenol-A epoxy, cured with diethylenetriamine.

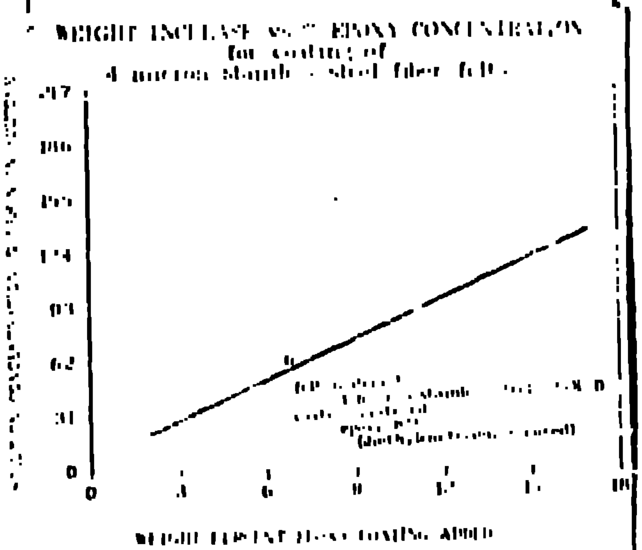


Figure 12.

The trend is toward higher percent solids content as the weight percent of added epoxy increases as shown in Figure 13. The additional epoxy coating simply fills available space within the fiber matrix.

*"Epon" resins trademark of Shell Chemical Co.

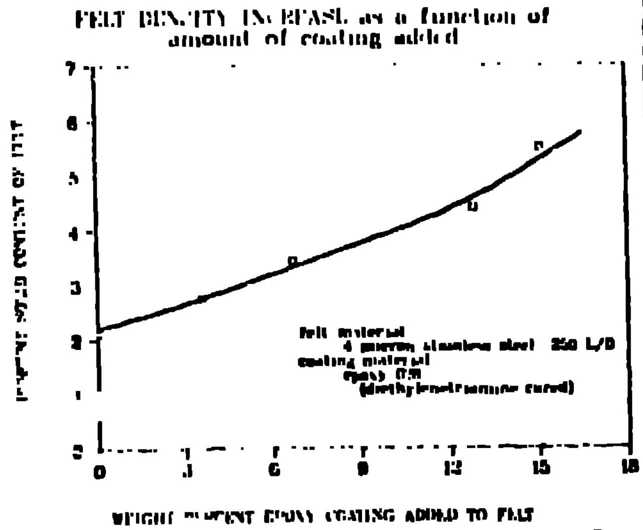


Figure 13.

The amount of epoxy pickup as a function of L/D shown in Figure 14 is not what one would intuitively expect. Smaller L/D ratios, or shorter fibers with more surface area per unit weight, might be expected to accept more coating.

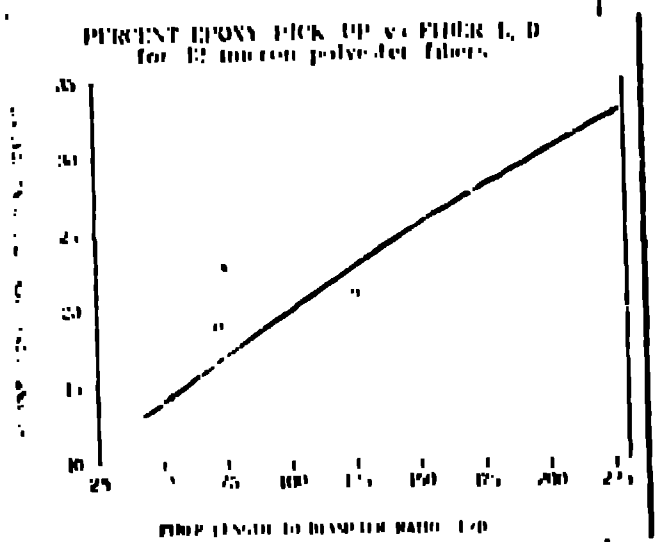


Figure 14.

However, the coating webs at fiber intersections, can be seen in Figs. 15 and 16. Longer fibers will have more intersections, which helps to explain the greater coating pickup data.

Figure 15. Webbing at intersections.

Figure 16. Concentration at intersections.

Uncoated polyester felts of various L/D's were compared in compression. Figure 17 shows that compressive strength increases for felts made from fibers of decreasing L/D.

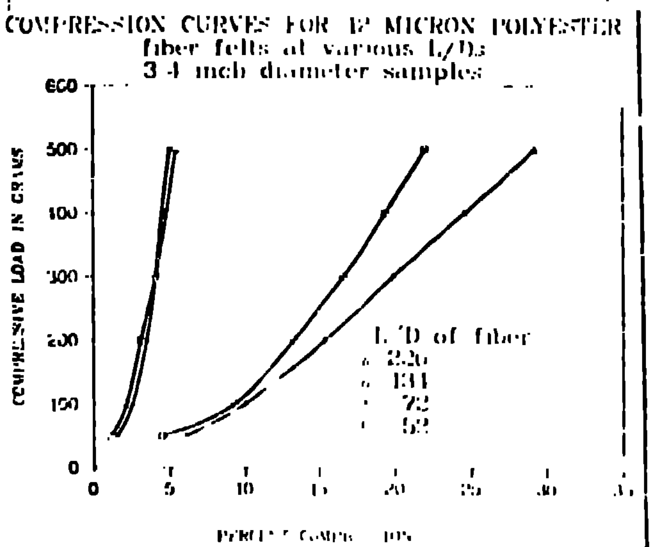


Figure 17.

In Figure 18, the effects of coating on two separate L/D fiber ratios are graphed. The coating ties ends and intersections together, causing fibers to flex rather than orient to the stress.

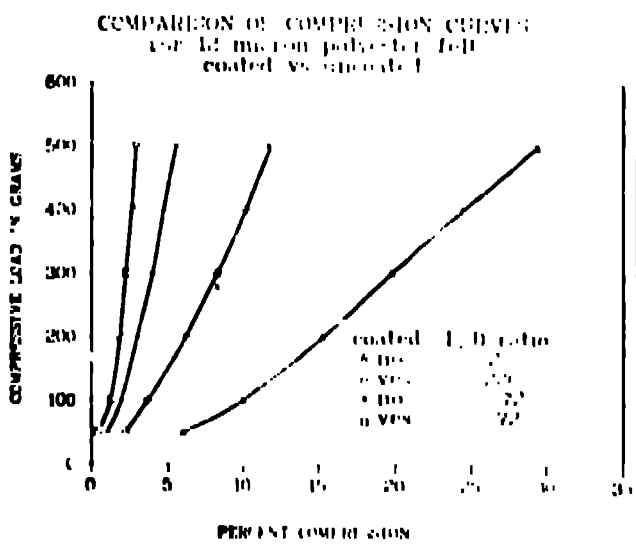


Figure 18.

Figure 19 shows plots for stainless steel felts with three different epoxy coating contents. By increasing the epoxy content 15%, compression for a given load is reduced at least 50%, yet total solids percent only increase by 3.

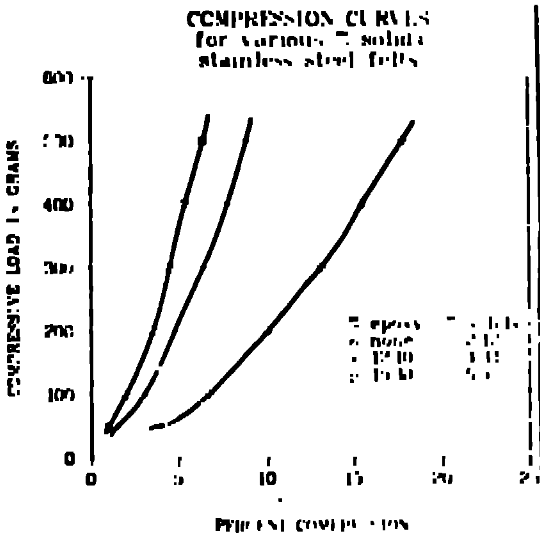


Figure 19.

By keeping the compressive load constant and varying fiber L/D, the curves in Figure 20 were generated. The solid line was drawn smoothly through the data. However, the dashed line might be a real condition. As fiber length increases, there may be a point at which a beam effect is observed. Once a rod buckles in the center its flexual properties abruptly become non-linear, which may be what is observed in the dashed line.

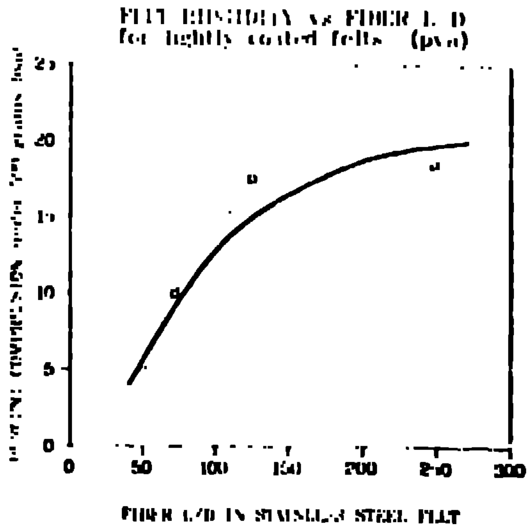


Figure 20.

Figure 21 shows percent compression as a function of percent solids. Increasing the solids content of a felt lowers the compression distortion under a given load.

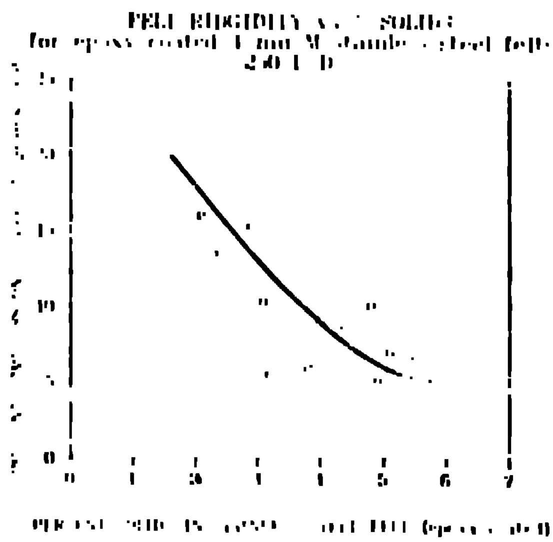


Figure 21.

4. TAILORING OF PROPERTIES

Fiber felting offers a method for tailoring the end properties needed in a low density structure. Density, for example, can be tailored in one or more of three ways. Selection of the fiber materials is one way to adjust density. The second way is to select an L/D to achieve a desired density. The smaller the L/D the higher the composite density (see Figure 10). The third way to adjust density is to vary the amount of coating added to the felt, as shown in Figure 13. Adjustments to other properties of a structural felt can also be made by changes in fiber material, L/D of fibers, and quantity and nature of the coating. There are trade-offs in designing properties. For example, for a given fiber material, in order to increase compressive strength it will be necessary to increase density. However, with the broad range of fibers commercially available, it might be possible to achieve the desired compressive strength at low density by selecting a higher-modulus fiber.

5. CONCLUSIONS

Low density structural composites with custom-tailored end properties can be made by felting and bonding fibers. Such structures can take advantage of the materials properties of the fiber, as well as the three-dimensional and low density properties of the matrix. Tailoring of properties is effected by varying the fiber material, L/D of fibers, and coating of the fibers.

The felting technique is applicable for making felts up to 12.7-mm thick reproducibly. Such structures are useful in compressive cushion applications, where the flexing of individual zero-creep fibers limits stress relaxation and compression set. The low density feature is attractive where weight or mass must be limited.

6. REFERENCES

1. "Polycarbonate Resin as a Hot Melt Adhesive," Stephen E. Newfield and E. P. Ehart, SPE 24, Dec. 1968.

BIOGRAPHIES

Stephen E. Newfield is the Section Leader of the Plastics Section of the Materials Technology Group of the Los Alamos Scientific Laboratory. He holds a B.S. in Chemistry from New Mexico State University and an M.S. in Electrical Engineering Computer Science from the University of New Mexico. He is involved in elastomers and polymers development, as well as composites and injection moldable ceramics and metals. He directs a group which provides service and development in most areas of elastomers, composites, adhesives, coatings, and conventional plastics.

John V. Milewski has over 31 years of industrial experience in the field of high strength and high temperature materials and composites engineering. He has specialized in plastics and fiber reinforced composites, whiskers, and other higher strength-fiber development and manufacturing, and recently has become involved in composite formulations and packing concepts for filler-fiber combinations. Dr. Milewski has given numerous technical presentations throughout the world on the efficient use of high strength fibers. He is the coeditor of the "Handbook of Fillers and Reinforcements" for Plastics and has over 20 technical publications in this field, and has been granted 18 patents.

Dr. Milewski is a licensed Professional Engineer in the state of New Jersey, and is a member of several professional societies.